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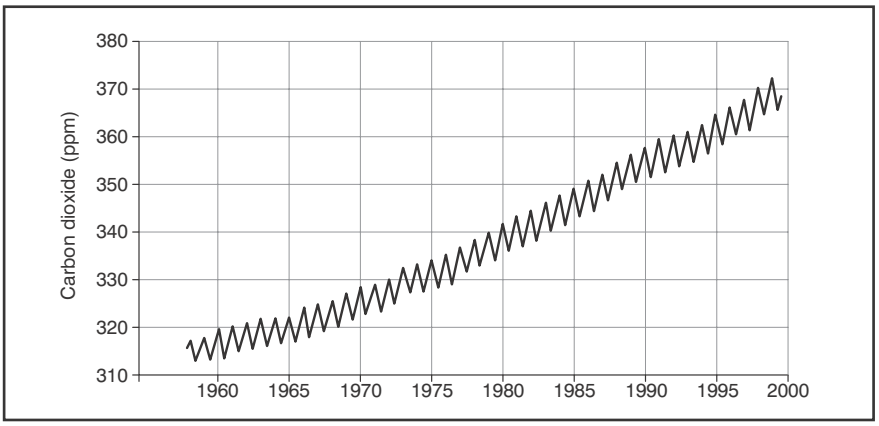
GLOBAL WARMING: HOPES AND IMPERATIVES

The greenhouse effect

The greenhouse effect describes abnormal heating of the earth's atmosphere. An accelerating accumulation of so-called greenhouse gases – water vapour, **carbon dioxide** (CO_2), **methane**, **nitrous oxides** and others – traps heat that would otherwise escape into space. The gases act just like a glass greenhouse, allowing short-wave radiation from the sun through to the earth, but then trapping some of the longer wavelength radiation that would otherwise be emitted back into the atmosphere. The earth, therefore, gets hotter.

Global warming is perhaps the most pressing environmental issue of our time – a huge global problem, the consequences of which will affect all humanity. This is because the world's population is growing rapidly, many **LEDCs** of the South, not least China and India, are industrialising, and fossil fuels are being burned at an accelerating rate. Since the (19th century) Industrial Revolution, CO_2 levels have already risen by a third and could, theoretically, double during the 21st century. Indeed, the famous Keeling Curve (Figure 1), illustrating CO_2 levels measured annually over the past 50 years, has become iconic in showing this inexorable rise. Furthermore, methane levels have already doubled, so thickening this 'chemical blanket' and changing climates, weather patterns and sea levels, with potentially alarming consequences. However, if there were no greenhouse gases, the earth's average temperature would be an incredibly low minus 18°C! Life as we know it could not exist. The problem today is that greenhouse gases are accumulating abnormally quickly, so hastening climatic changes already experienced repeatedly throughout geological time.

Figure 1: The Keeling Curve - 50 years of recorded CO_2 increases, measured at Mauna Loa Observatory in Hawaii



Climatic predictions for our future

So what exactly is projected for our future? Sophisticated computer global climate models (GCMs), whilst not perfect, are excellent at simulating atmospheric conditions, using past climate records and 'proxy' evidence from ice cores, **dendrochronology** and so on. They cannot predict climate changes at a regional (and so local) scale, but, combined with a wealth of corroborative evidence, allow researchers to predict future climatic scenarios. For example, a sequence of reports from the Intergovernmental Panel on Climate Change (IPCC) project temperatures in 2100 which range from an increase of 1.1°C (should global greenhouse gas emissions fall sharply), up to an apocalyptic 6.4°C increase in their highest emissions scenario. These figures may seem small, and they are predicted averages which, of course, might mask wide variations. In geological terms however small changes assume enormous significance. The average temperature difference between the last Ice Age and today, for example, is only 4°C!

A 1°C increase since the start of the Industrial Revolution is already almost upon us. A change barely perceptible to human skin, the rise may continue to nearer 2°C. Some would say this will happen regardless of global CO_2 control and reduction initiatives already implemented and planned. This is because the oceans gradually absorb heat generated by extra greenhouse gases (like a great heat sink), only to eventually release it decades later. Others are less pessimistic. But within the next 40 years, the following may well have to be contemplated – and could even be inevitable:

- more intense rainfall events, causing localised flooding
- perennial droughts in the western United States
- Alaskan settlements and infrastructure sinking into the melting permafrost (see **Geofile** Online 566, April 2008)
- Europeans dying of summer heatstroke
- substantial retreat of mountain glaciers (Figure 2)
- more forest fires
- stronger 'Katrina'-type tropical revolving storms
- significant species extinctions
- low-lying coastal regions and cities threatened by sea-level rise
- falling tropical crop yields (yet increased production in temperate latitudes)
- major environmentally driven migrations (with increased potential for conflict).

The predicted consequences of yet higher temperature rises ratchet up the threats. For example, 80% of Arctic sea ice could melt and major species extinctions could occur with a rise of 3°C, and there would be millions of storm, fire, drought, hunger and coastal flooding refugees with a rise of 4°C. Apocalyptic scenarios abound at these figures, because the most dangerous feedback of all – the irreversible thaw of permafrost – will have kicked in, and there are as yet no agreed estimates of the potential effect of the methane that would then be released. Given the probability of plummeting global food production, hundreds of millions hungry, a fifth of humanity

Figure 2: Spielboden Glacier, Saas Fee, Switzerland - the glacier last touched the terminal moraine (now marked by a ridge of conifers) in 1855

affected by flooding, Amazonian rainforest collapse (indeed major changes to 40% of the world's ecosystems), the 3°C to 6°C increases, frankly, do not bear thinking about. Earth has been there before: 251 million years ago, at the end of the Permian geological period, global temperatures rose by 6°C, and 95% of all species were wiped out.

Focusing on Britain alone sharpens our awareness further. In June 2009 the UK Climate Impact Programme (UKCIP) published a stark report highlighting the threats facing Britain should global CO_2 emissions continue to rise. The research, by scientists from the Met Office and the University of Oxford, updates a 2002 study. Improved, detailed projections for Britain this century again adopt a variety of emission scenarios. Over the next 20 to 30 years, summers over 2°C hotter than at present are thought to be inevitable because of emissions already released. (The hottest 10 years on record have already been recorded since 1990.) Furthermore, milder but wetter winters are certain too. However, bleaker prospects projected for the rest of this century depend upon the outcome of negotiations at the United Nations Climate Summit in Copenhagen (Box 1).

Rising sea levels, increased storm surges and torrential summer rain could put 800,000 homes at risk of devastating flooding – double the present number. Indeed, increasing wind, and alternating years of drought and flooding were forecast in 2007. In short, Britain's temperate maritime climate, so strongly influenced by the unstable 'polar front' boundary between competing air masses will become increasingly unpredictable. Only Scotland is likely to retain precipitation all year round, with less rain in the summer and more in the winter everywhere else. Wales and Cornwall, for example, will be much drier than at present. Furthermore, East Anglia could see up to 60% less rainfall in summer, turning it into an arid zone - with potentially devastating impact on its agricultural productivity. Temperature predictions also show regional variations with up to 6°C increases forecast by 2080 – exacerbating the risk of skin cancers and insect-borne diseases. In addition, droughts and life-threatening heatwaves will be particularly acute in urban areas, with London most at risk. Summer temperatures here could reach a searing 45°C – the equivalent of Marrakesh, Morocco, today! Government directives to more than 100 public sector organisations – including the NHS, Army and Police – are now certain, in order to develop and publish contingency plans on how they intend to respond to the dangers.

Not just in Britain, but worldwide, such projections have stimulated unprecedented levels of international cooperation between scientists, governments, industries, environmental pressure groups and individual citizens – all to prepare for a future of undoubted change. A global 2°C increase above pre-industrial levels as a necessary, but achievable temperature limit is now agreed by all as official policy – not least the IPCC and European Union. This equates to keeping greenhouse gas levels below 450 **ppm**. Technological, political, economic and collective individual actions can – and must – make this possible.

Technological responses

Most of the technologies required to curb greenhouse gas emissions are already mastered, or could be developed, given sufficient political will and financial investment. In 2004, Steve Pacala and Robert Socolow of the USA's Princeton University published a realistic 50-year strategy – notably containing nothing to promote economic meltdown or challenge our established, or hoped for, quality of life. Their 'solutions' included:

- halving the average distances travelled by cars – and doubling car engine fuel economies
- converting coal-fired power stations to natural gas – with carbon capture and storage (CCS) for all
- increasing the use of biofuels – so long as virgin rainforest isn't cleared to grow them
- doubling the amount of nuclear power – arguably politically now feasible, given the exceptional efficiency and passive 'walk-away' safety systems of the latest designs
- increasing the area under solar panels by a factor of seven hundred
- stopping all tropical deforestation – and planting 300 million hectares of new trees
- reducing carbon emissions from buildings and appliances by a quarter – through more efficient insulation, lighting and appliances.

Just to put the relative simplicity of all this into perspective, the International Energy Agency (IEA) estimates that standby (light) modes currently left on world-wide account for 1% of all greenhouse emissions. We might think this to be an insignificant fraction, yet the entire aviation industry globally doesn't account for that much more! (That

standby lights cost us on average £200 per person to power each year, the incomprehensibility of our idleness seems even more absurd.)

Note also Pacala and Socolow's relatively underplayed references to alternative energy – yet the future scope of such energy sources for the generation of electricity is considerable. The UK government already targets 20% renewable generation by 2020 (excluding nuclear power). Given existing hydroelectric power generation, rapid development of on- and off-shore wind farms, and the considerable potential of tidal power (for example, the Severn Estuary), this is not unrealistic. Elsewhere, geothermal, solar (photovoltaic panel), nuclear fusion (as opposed to the radioactive waste-producing fission technology currently adopted) research is evolving rapidly from simply 'exciting in theory' to practical application. Such research arguably only now needs serious financial investment to turn the technologies into practical, large-scale, efficient, low-carbon electricity generation systems in practice.

Political and economic considerations

Internationally, the economic and political aspects of combating climate change are much more difficult to be positive about. However, the politically influential 2007 Stern Report found the likely costs of meeting necessary targets for reducing greenhouse gas emissions surprisingly low. Political initiatives abound, but the most workable and significant are both national and international 'cap and trade' schemes whereby participants have, by law, to 'cap' their carbon emissions every year. Permits defining each cap can then be 'traded' very profitably by the most efficient to those polluters going over their limit. As a way of encouraging energy efficiency, such schemes are admirable – not least if the caps are reduced each year.

Following a 2003 declaration to reduce its CO_2 emissions by 60% (by 2050), the UK continues to lead by example. Indeed, it set up the world's first carbon trading scheme in 2004. A variation of this scheme has now been adopted throughout the European Union. Since then, notably, legally binding UK governmental commitments to reduce all greenhouse gas emissions (not just CO_2) by 80% demonstrate world leadership in tackling climate change – admirable endorsement of the famous 1997 Kyoto Protocol obligations (Box 1).

Box 1: Second time 'lucky'?

The United Nations Climate Summit in Copenhagen (December 2009) may represent a unique moment in modern history – when a worldwide agreement on global warming is finally reached.

The conference in Denmark will try to reach an agreement that all previous attempts have failed to achieve. There is, however, far greater optimism this time around. The political will for change is strong, not least given the appointment of a new 'green' US President (see Box 2) and overwhelming scientific evidence of climate change.

Nevertheless, any agreement will need to delicately balance how the 'burden' of greenhouse gases will be shared. For example, China as the world's fastest growing economy now exceeds the USA as the world's biggest CO_2 polluter. But is it fair for China to cut emissions at the risk of economic slowdown, when the USA industrialised with few environmental controls? The morality of climate change is not new.

The Kyoto Protocol was adopted in Kyoto, Japan, in December 1997. It was the first attempt at setting binding targets to cut greenhouse gas emissions. Arguably modest, the targets were set at an average of 5% reduction against 1990 levels over the five-year period 2008 to 2012. Under the principle, 'common but differentiated responsibilities', **MEDCs** take more of the economic burden. Nevertheless, despite signing the Protocol, China and several MEDCs, including Canada and Japan, were slow to ratify the agreement. The USA has failed to ratify the Protocol at all. Many are hoping that the optimism gathering for December 2009 will not prove short-lived.

Box 2: A 'green' USA?

On 20 January 2009 Barack Obama was inaugurated as the US President. He has been elected on the promise of change and within days of taking office, was swift to set his administration apart from the environmentally hesitant policies of former President Bush. President Obama's predecessor was strongly criticised for failing to acknowledge the extent of the global warming problem and to agree to global limits on the emission of greenhouse gases.

Hailed by environmentalists as the first 'green president', Obama has stated: 'Now is the time to meet the challenge of this crossroads of history, by choosing a future safer for our country, prosperous for our planet, and sustainable.'

President Obama's new agenda on climate change includes:

- appointment of a new special envoy for climate change
- car manufacturers forced to produce more fuel-efficient vehicles
- individual states will be able to set tougher standards for vehicle emissions; previously one (modest) standard was to be applied to all states
- federal government buildings to be made more energy-efficient
- a doubling of capacity for 'green' energy generation over the next three years.

Around the world, politicians and environmentalists alike, wait to see if the world's second greatest carbon emitter and the planet's largest economy are finally able to take a lead on tackling climate change.

Positive individual actions

Individual responses to combat climate change will be just as important as political ones. Every one of us has a positive role to play – incidentally saving us money in the long run! Collectively our choices and actions matter – and will make a significant difference. For example:

- calculating our 'carbon footprint' (http://www.carbonfootprint.com) is a good start. This will enable us to understand which areas of our lives have most impact – and which behaviours we will (realistically) be able to change
- driving less, sharing journeys, using public transport or walking and staying healthy

- reducing our 'food miles' by sourcing locally produced, seasonal produce wherever possible
- switching off electrical devices at the wall
- insulating homes efficiently – so allowing the thermostats to be turned down
- replacing all light-bulbs with low-energy alternatives – which also last much longer
- recycling and re-using. For example, every supermarket plastic bag re-used is one less emitting methane on a landfill site
- buying energy-efficient appliances. For example LCD flat-screen televisions use a fraction of the power of their plasma alternatives
- flying less or choosing a young, energy-efficient, airline. Also consider offsetting the CO_2 emissions of a flight through a reliable Gold Standard company (see below).

Finally, 'going carbon neutral' is realistic by buying carbon offsets to compensate for our calculated emissions. Various **NGOs** have grouped together to create an independent Gold Standard for offsetting projects. Only rigorously vetted renewable and efficient energy projects, for example in LEDCs, are awarded the standard. Providing we all strictly support such monitored projects, every tonne of our own emissions would pay for an equivalent reduction elsewhere – such as by providing solar panels for an Indian village rather than a diesel generator.

Saving the planet or saving our future?

Cynics and sceptics protest that all this saving the planet 'gush' is a load of hot air! They repeatedly state that climate change follows natural cycles and every environmental bandwagon (such as the 1970s threats of a new Ice Age) is discredited in the fullness of time. As indicated earlier, the planet has already seen significant climatic change, albeit over geological time – and has proved its capacity to adapt and change. But humankind as we know it was not around to face the consequences. Perhaps saving our future might provide a more thought-provoking perspective – certainly the future of our children and grandchildren amongst a world population projected to reach 9.2 billion by 2050. In short, the science of human-enhanced global warming is proven, and there is time to address the threats. There is hope – but it is up to all of us to make it happen.

Glossary

Carbon dioxide (CO_2) accounts for about 50% of global warming. Most comes from the burning of fossil fuels since the start of the Industrial Revolution. Burning of the tropical rainforests, at an average rate of over 40 ha a minute, is another major source. (Remember – trees take CO_2 from the air, and lock up the carbon as they grow.)

Carbon capture and storage (CCS): technology currently being developed to replace the pumping of industrial and power-station fossil fuel CO_2 into the atmosphere. It is envisioned that either chimneys in built-up areas would draw in polluted air, allowing minerals to soak up the CO_2, or it would be captured directly before emission. The CO_2 would then be stored underground, perhaps in liquid form, in empty oil or gas fields.

Dendrochronology: tree-ring dating using annual growth rings – the thickness of each ring is an indicator of growth and so indicates climatic conditions.

LEDCs: less economically developed countries.

MEDCs: more economically developed countries.

Methane: the second most potent greenhouse gas, and 20 times more effective at trapping heat than CO_2. Methane emissions from ever-increasing numbers of cattle are growing even faster than CO_2. Microbe activity in (rice) padi fields, the burning of industrial waste, plus emissions from melting permafrost, landfill sites, coal mines and natural gas pipelines all account for significant proportions too.

NGOs: non-governmental organisations, for example Oxfam or Greenpeace.

Nitrous oxides are steadily increasing too – again associated with the burning of fossil fuels, but also released by fertilisers.

ppm: parts per million. For CO_2 and any other gases that are sparse in the air we use this term (rather than the 0.0001% it represents). During Ice Ages CO_2 levels are low at between 180 and 190 ppm. During warmer climatic periods CO_2 might be expected to reach a high of 290 ppm. However, CO_2 reached 385 ppm in 2008 and is still rising at between 2 and 3 ppm per year!

Websites

http://www.ipcc.ch/ (Intergovernmental Panel on Climate Change)

http://www.wmo.int/pages/index_en.html (World Meteorological Organisation)

http://www.carbonfootprint.com (to calculate your carbon footprint)

www.nature.com/climate/index.html (for up-to-date science on climate change)

http://www.energysavingtrust.org.uk (for advice on saving energy)

http://www.metoffice.gov.uk (Met Office)

Focus Questions

1. To what extent is global warming a result of human activity? You may wish to include an annotated diagram to illustrate your answer.

2. Energy conservation is one approach towards lessening the effects of global warming. Describe and explain why 'local solutions' are one sustainable approach to tackling the 'global warming problem'.

3. 'The effects of global warming mean that it will get worse before it gets better'. Discuss.